

### Use of Barrier Analysis in NRC Staff's Performance Assessment Reviews

Performance and Risk Assessment Community of Practice
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United States Nuclear Regulatory Commission

### **Outline**



- What is a barrier analysis?
- How does NRC use barrier analysis in our reviews?
- Barrier analysis review examples
- Final thoughts

### What is a Barrier Analysis?



- Identification and description of barriers in a performance assessment
- Function of barriers in limiting or delaying timing of releases or exposures; or reducing likelihood of releases or exposures
- Can be qualitative or quantitative
- Natural and engineered barriers are considered

### What is a Barrier Analysis



- Examples of types of quantitative barrier analyses
  - One-off analyses
  - One-on analyses
  - Factorial designs
- Qualitative description of barrier functions and capabilities

### What is a Barrier Analysis



### Example of a Factorial Analysis

<u>#1</u>	#2	#3	#4	<u>#5</u>
off	on	on	on	on
on	off	on	on	on
on	on	off	on	on
on	on	on	off	on
on	on	on	on	off
off	off	on	on	on
off	on	off	on	on
off	off	off	on	on
			••	
off	off	off	off	on

# How Does NRC Use Barrier Analysis?

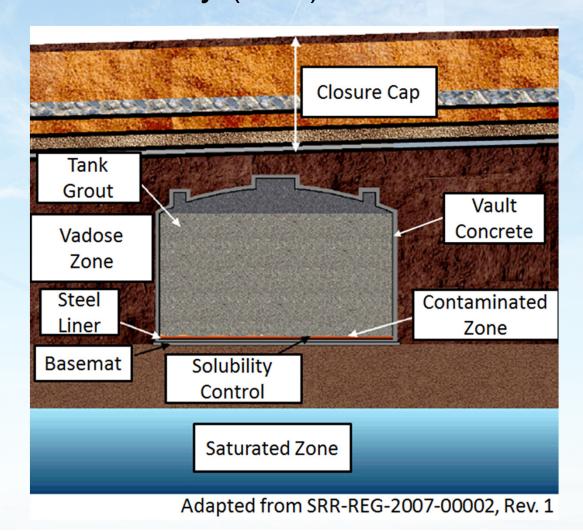


- To focus reviews and monitoring activities on areas most important to risk
  - To ask better questions
  - To make better decisions
- To better understand system behavior
- To evaluate impact of challenges to disposal facility performance
- To evaluate impact of uncertainty with respect to barrier performance
- To focus data collection and research efforts

# Barrier Analysis Examples: Savannah River Site (SRS)

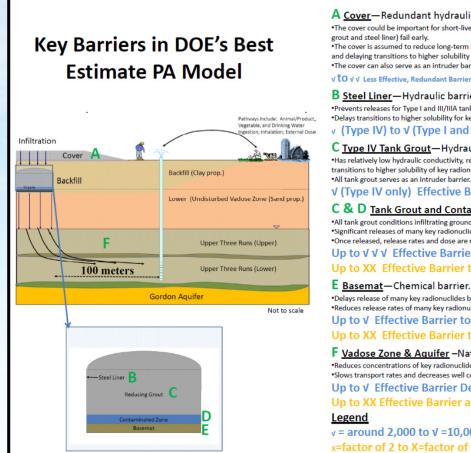


### F-Tank Farm Facility (FTF) Barriers





### Qualitative Barrier Analysis Example



#### A <u>Cover</u>—Redundant hydraulic barrier; provides defense-in-depth.

- •The cover could be important for short-lived and other radionuclides , if other hydraulic barriers (i.e., tank
- •The cover is assumed to reduce long-term infiltration rate from 15 to 12 in/yr, leading to lower release rates and delaying transitions to higher solubility for key radionuclides.
- The cover can also serve as an intruder barrier and enhances site stability through erosion protection.
- v to v v Less Effective, Redundant Barrier to Timing of Release

#### B Steel Liner—Hydraulic barrier.

- •Prevents releases for Type I and III/IIIA tanks until after 10,000 years in DOE's reference case.
- •Delays transitions to higher solubility for key radionuclides.
- √ (Type IV) to √ (Type I and III) Effective Barrier to Timing of Release

#### C Type IV Tank Grout—Hydraulic barrier.

- ·Has relatively low hydraulic conductivity, reducing release rates during the performance period and delaying transitions to higher solubility of key radionuclides.
- ·All tank grout serves as an intruder barrier.

#### V (Type IV only) Effective Barrier to Timing of Release

#### C & D Tank Grout and Contaminated Zone—Chemical barrier.

- •All tank grout conditions infiltrating groundwater enhancing low solubility of ke y radionuclides.
- \*Significant releases of many key radionuclides do not occur for 1000s to 10s of 1000s of years.
- Once released, release rates and dose are reduced.

#### Up to $\sqrt{\sqrt{V}}$ Effective Barrier to Timing of Release

#### Up to XX Effective Barrier to Magnitude of Release

- •Delays release of many key radionuclides by 1000s of years.
- •Reduces release rates of many key radionuclides by greater than a factor of 10.
- Up to √ Effective Barrier to Timing of Release (e.g., Np, Pu)

#### Up to XX Effective Barrier to Magnitude of Release (e.g., Np, Pu)

#### F Vadose Zone & Aquifer -Natural attenuation of releases.

- •Reduces concentrations of key radionuclides by approximately 10X through dilution.
- Slows transport rates and decreases well concentrations of some key radionuclides via sorption.
- Up to V Effective Barrier Delaying Timing of Peak Release (e.g., Pu)

#### Up to XX Effective Barrier at Reducing Well Concentrations (e.g., Pu)

 $\sqrt{1000}$  = around 2,000 to  $\sqrt{1000}$  = 10,000 yr delay in timing of peak dose x=factor of 2 to X=factor of 10 reduction in peak dose



### Quantitative Barrier Analysis Example

		Тс	Pu	Np
1	Total Barrier Performance Needed (Function of Inventory)	6 (Type 1)	9 (Type IV, Tank 18)	6 (Type I)
2a	Final Solubility Control	0	2	1 to 2
2b	(Initial Solubility Control)	(9 to 11)	(9 to 11)	(5 to 6)
3	Basemat Attenuation (Sorption)	<1	2	2
4	Near-Field Diffusion or Dispersion	2	1	1
5	Aquifer Dilution	1	1	1
6	Sorption	<<1	1	<<1
7	Additional Dispersion to POC	1-2	1	1
8	Total Barrier Performance	5	8	6 to 7
9	Calculated Safety Margin (calculated to peak dose)	-1	-1	0 to 1



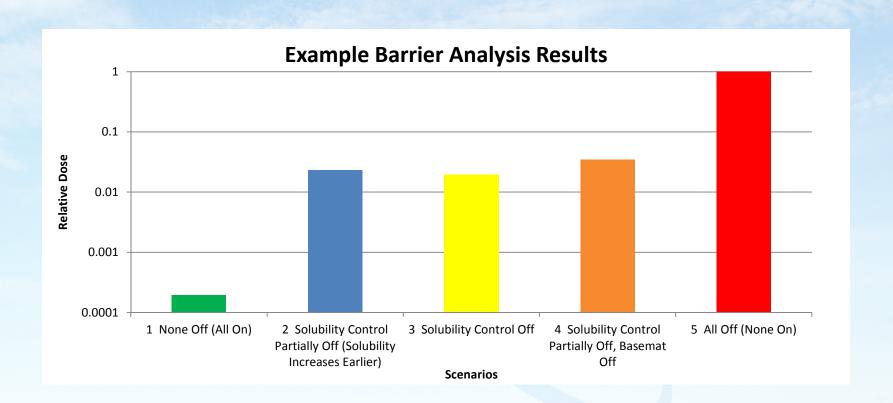
### Partial Factorial Barrier Analysis Example

Barriers	States (Worst to Best)		
Solubility Control	Low Solubility Control (Very High Solubility Limit)	Moderate Solubility Control (Moderate Solubility Limit)	High Solubility Control (Low Solubility Limit)
Basemat Sorption	None (No sorption or by- Pass)	Moderate to High Sorption (High K <sub>d</sub> )	
Natural System Sorption	Low Sorption (Low K <sub>d</sub> )	Moderate Sorption	High Sorption (High K <sub>d</sub> )

	Solubility Control	Basemat Sorption	Natural System Sorption	
Case 1 None Off (All On)	High	Moderate to High	High	
Case 2 Solubility Partially Off **Solubility Increases Earlier	Moderate	Moderate to High Moderate		
Case 3 Solubility Control Off	Low	Moderate to High	Moderate	
Case 4 Solubility Control Partially Off, Basemat Off (By-Pass)	Moderate	None	Moderate	
Case 5 All Off (None On)	Low	None	Low	



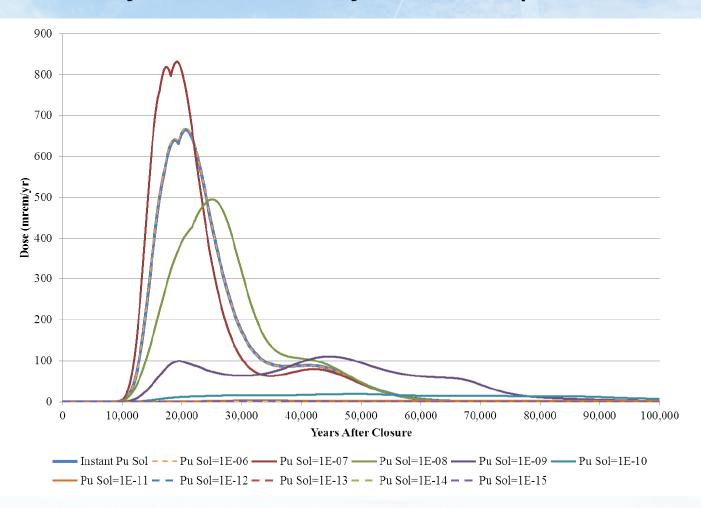
### Partial Factorial Barrier Analysis Example



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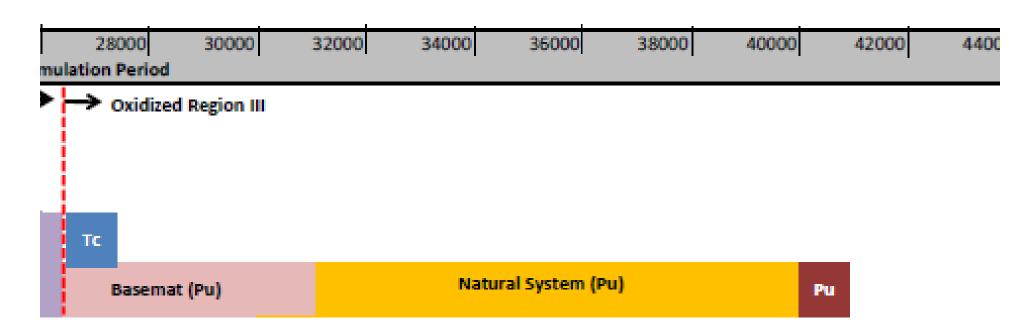


### Sensitivity/Barrier Analysis Example





#### Barriers to Timing Example



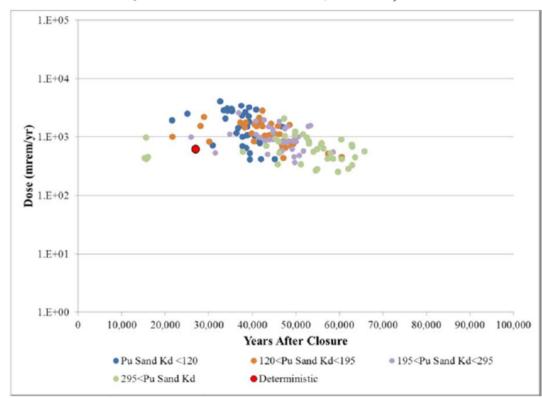


### Binning Results to Identify Important Barriers

Figure 1: Indicating

Figure 2: Fig Indicatin Ind Aquifer \( \) Aqu

Figure 3: Indicatin Aquifer V Figure 4: 100,000-Year Peak MOP Doses at the Well of Maximum Concentration, Indicating Plutonium  $K_d$  Values for Sandy Soil (Less Gordon Aquifer Well Depths, Tc OxII Sol. Limits = 3.0E-13, and Pu OxII Sol. Limits  $\neq$  4.0E-14)

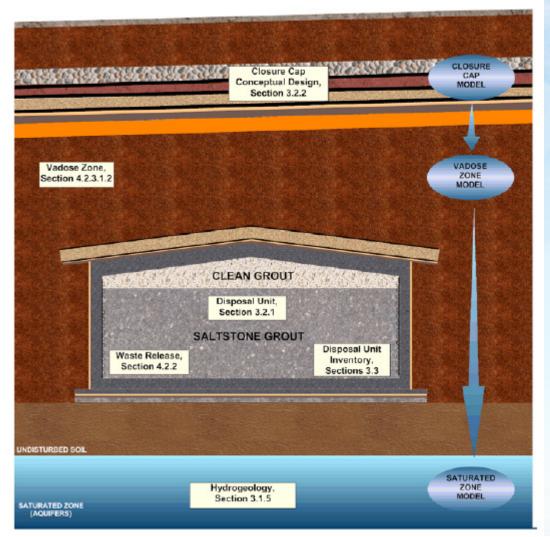


A) All Cases Configuration (286 - 138 = 148 realizations)

A) An Cases Configuration (5/0 - 204 - 200 realizations)

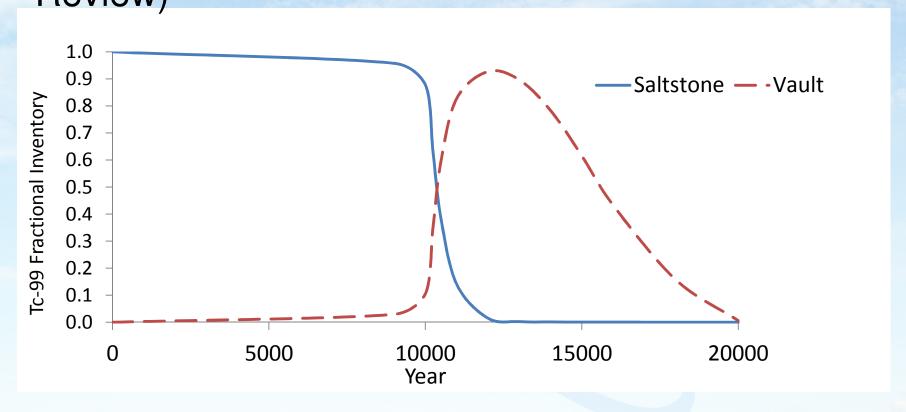
# Barrier Analysis Examples: SRS Saltstone Disposal Facility (SDF)

SDF Barriers (2009 PA)





Analysis of PORFLOW Output (Related to 2009 PA Review)





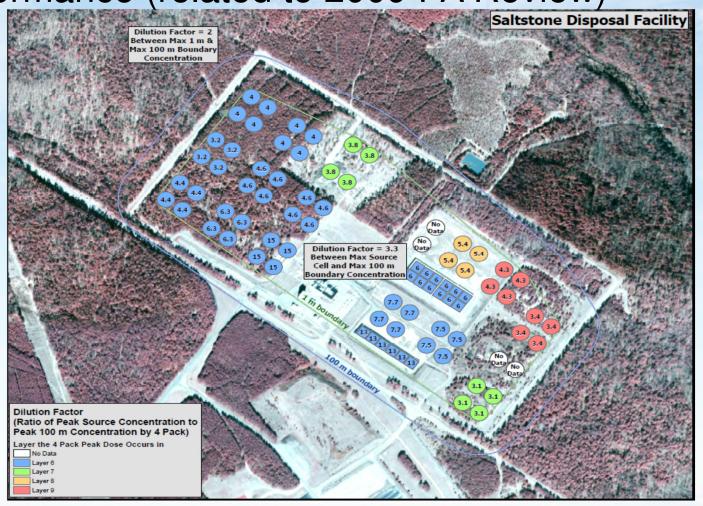
### Re-ran PORFLOW Model to Consider Alternative Barrier Performance (related to 2009 PA review)

(Highlighted values indicate values changed since the previous test.)

	Saltstone K <sub>d</sub> (mL/g)		Disposal	Post of the second	Final	Time of	Dose
	Reduced	Oxidized	Unit K <sub>d</sub> (mL/g)	t K <sub>d</sub> Fracturing	Fracture Spacing (m)	Peak Release Rate (yr)	Estimate <sup>1</sup> (mrem/yr)
DOE Case K1	500	0.8	500 to 217	Log	0.1	12,800	90
Test 1	500	0.8	500 to 217	Quadratic	0.1	12,100	86
Test 2	500	0.8	0.8	Quadratic	0.1	8730	680²
Test 3	500	0.8	0.8	Log	0.1	10,300	930²
Test 4	500	0.8	0.8	Quadratic	1	19,100	25
Test 5	139	0.8	0.8	Quadratic	1	10,100	35

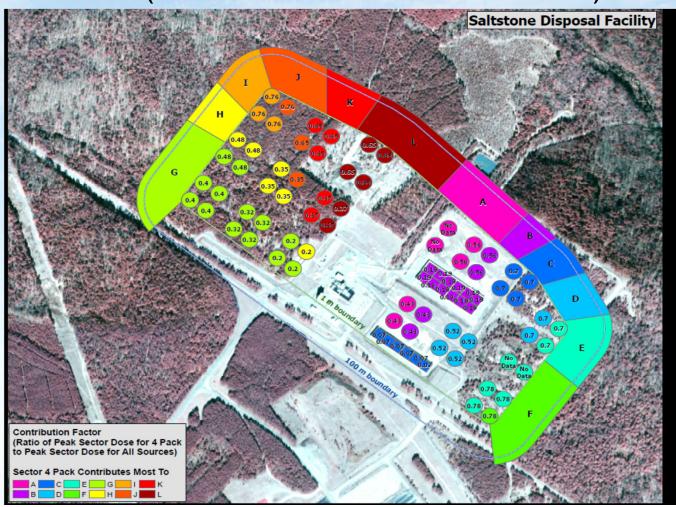


Re-ran PORFLOW Model to Study Natural System Performance (related to 2009 PA Review)



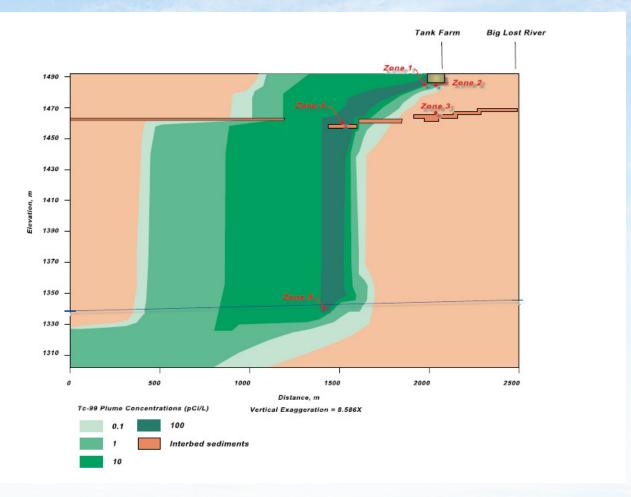


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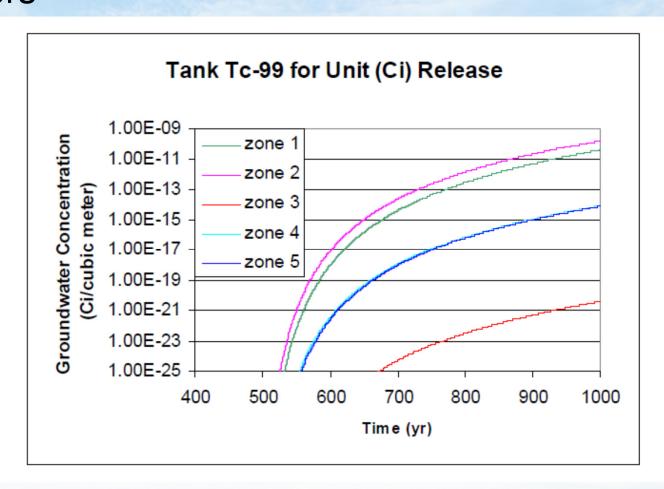


Tracking of Peak Plume Concentrations Through Barriers





### Tracking of Peak Plume Concentrations Through Barriers





Impact of Assessment Endpoint on Barrier Contributions



### **Final Thoughts**



- Barrier analyses can contribute substantially to better understanding model performance and potential modeling issues
- Barrier analysis can help reviewers ask better questions and focus on areas that are most important to risk
- Barrier analyses are important to understanding the impact of challenges to the disposal system
- Barrier analyses facilitates communication between stakeholders
- Barrier analysis contributions are a function of assessment endpoints including point of compliance and period of performance

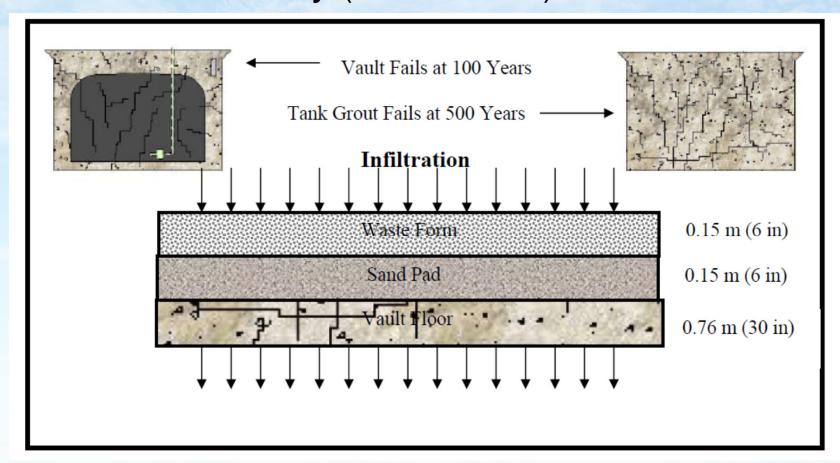
### Additional slides if needed





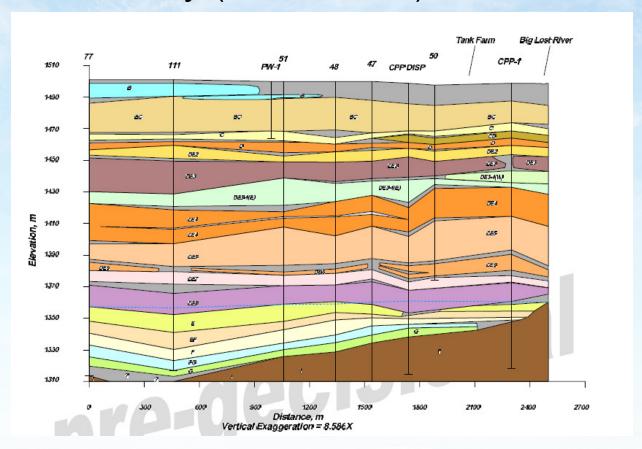


Idaho Nuclear Technology and Engineering Center Tank Farm Facility (INTEC TFF) Barriers



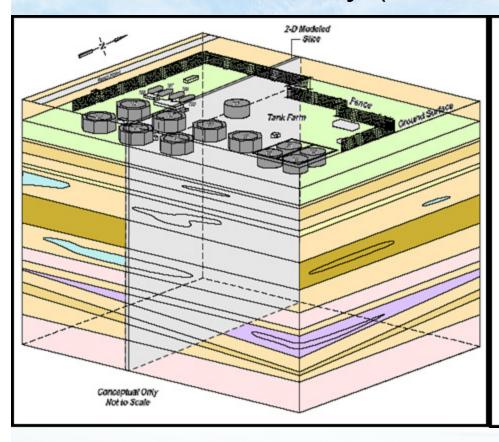


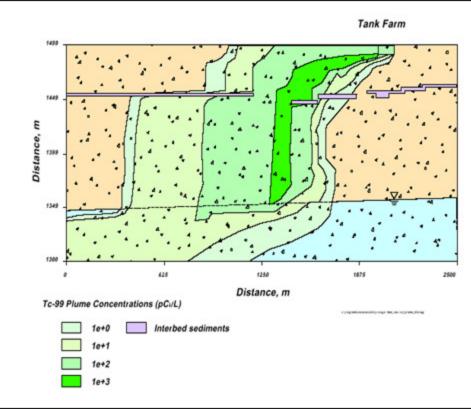
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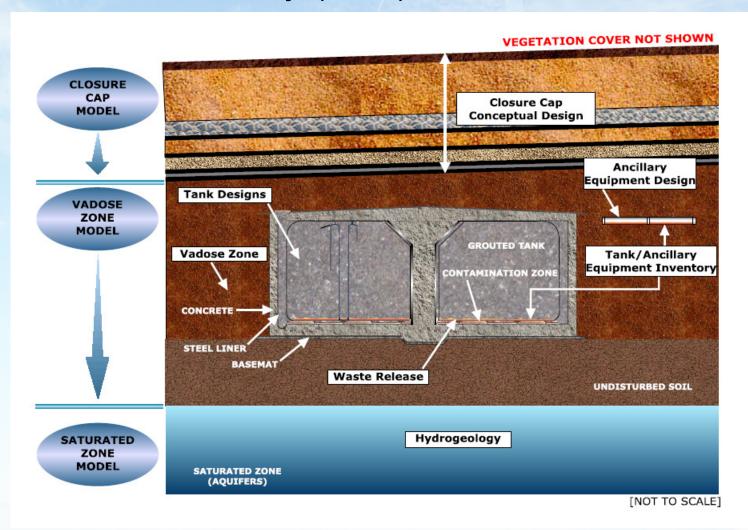
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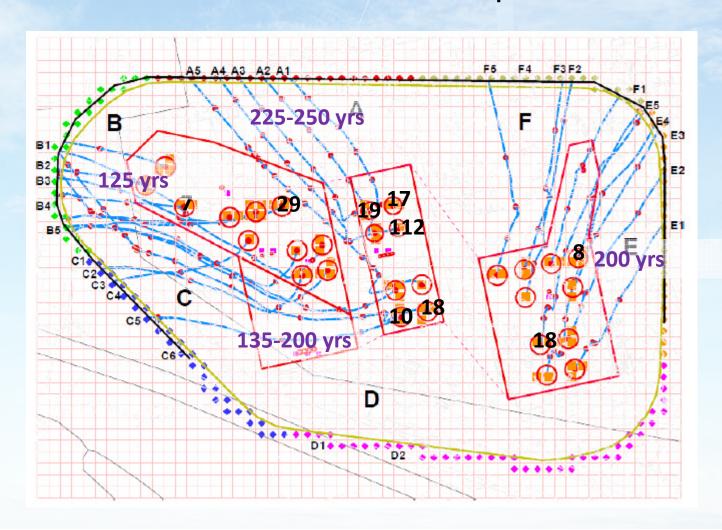


### H-Tank Farm Facility (HTF) Barriers





### Dilution/Attenuation Factor Example





### Single Natural System Barrier Example

- Type I Tanks--Attenuation factors are 15-40 from the source to the 1-m boundary and 1.3 to 3 from the 1-m to the 100-m boundary for Tc-99. Dispersion, cumulative impacts relatively significant (trade-off).
- Tank 18--Attenuation factor is 5 from the source to the 1-m boundary and 10 from the 1-m to the 100-m boundary for Pu-239. Dispersion, cumulative impacts less significant.

